5.2 Hardened Concrete Tests

5.2.1 Absorptivity, F-T, Compressive Strength, and Maturity

Several standard hardened concrete tests were performed on all mixtures, as listed below:

- Absorptivity, (ASTM C1585 Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes).
- Freeze-thaw testing, (ASTM C666 Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing, Procedure B – freezing surrounded by air).
- Compressive strength at 3, 7, 14, 28, and 90 days, (ASTM C39 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens).

The results from these tests are summarized in Tables 7-9. For the Phase III very low air content mixtures, the ASTM C666 F-T testing was expanded to also include freezing surrounded by water (Procedure A) and freezing surrounded by a 4.0 wt. % $CaCl_2$ brine. The results from the three variations of ASTM C666 F-T test are listed in Table 10.

Maturity tests, (ASTM C1074 Standard Practice for Estimating Concrete Strength by the Maturity Method) were performed only on the Phase II high air content and low air content mixtures, as summarized in Tables 11 and 12. For all mixtures, Figures 20-24 show compressive strength gain plots, Figures 25-29 show absorptivity plots, and Figures 30-36 plot changes in the relative dynamic modulus of elasticity (RDME) during F-T testing. Figures 37-39 plot changes in weight during F-T testing for the Phase III very low air content mixtures.

5.2.2 Additional F-T Testing

After completion of the F-T testing on the Phase II concrete mixtures, beams from the following Phase II concrete mixtures were selected for additional F-T testing under several variations of the Procedure A regimen, i.e. freezing surrounded by water, freezing surrounded by a 4.0 wt. % (0.72 mol/L Cl^-) $CaCl_2$ brine, and freezing surrounded by a 4.2 wt. % (0.72 mol/L Cl^-) NaCl brine:

- HI-VR-PC-6SK-45WC
- HI-VR-PC-5SK-45WC
- LO-VR-PC-6SK-45WC
- LO-VR-PC-5SK-45WC
- LO-VR-PC-6SK-50WC
- LO-VR-PC-5.5SK-52WC

Table 13 summarizes the results of the extended F-T testing.

Table 7: Hardened concrete test results for absorptivity, F-T durability, and compressive strength for Phase II high air content mixtures.

Mixture ID	Absorptivity ($mm^2/sec^{1/2}$)				F-T	Compressive Strength (psi)					
	Initial Slope	R	Secondary Slope	R	DF @ 300 Cycles	1 day	3 days	7 days	14 days	28 days	90 days
HI-VR-PC-6SK-45WC	2.00E-03	0.996	8.71E-04	0.994	103	2122	3422	3980	4391	4811	5477
HI-VR-PC-6SK-45WC	1.71E-03	0.993	6.50E-04	0.993	103	2474	4154	4659	5027	5438	6276
HI-SYN-PC-6SK-45WC	2.22E-03	0.993	1.14E-03	0.997	103	2332	3836	4534	5199	5676	6321
HI-SYN-PC-6SK-45WC	2.30E-03	0.994	1.23E-03	0.997	103	2414	3889	4628	4952	5372	6280
HI-VR-SLG-6SK-45WC	1.34E-03	0.990	5.72E-04	0.992	103	1188	2996	4488	5176	5921	6230
HI-VR-SLG-6SK-45WC	1.81E-03	0.975	6.54E-04	0.989	103	1220	3298	4803	5741	5816	6381
HI-SYN-SLG-6SK-45WC	3.16E-03	0.980	6.27E-04	0.995	102	-	-	5533	6504	7097	7491
HI-SYN-SLG-6SK-45WC	2.84E-03	0.996	1.18E-03	0.998	103	-	-	5386	6292	6816	7593
HI-VR-FA-6SK-45WC	1.87E-03	0.961	4.30E-04	0.993	101	2512	3877	4388	4801	5047	6026
HI-VR-FA-6SK-45WC	1.80E-03	0.992	5.91E-04	0.991	99	2303	3578	3900	4480	4921	5436
HI-SYN-FA-6SK-45WC	3.18E-03	0.986	1.33E-03	0.992	101	1818	2602	2870	3377	3605	3967
HI-SYN-FA-6SK-45WC	3.49E-03	0.984	1.33E-03	0.994	98	1801	2614	3259	3319	3841	4334
HI-VR-PC-5SK-45WC	2.52E-03	0.997	1.17E-03	0.995	101	2244	3776	4610	4677	5299	5717
HI-VR-PC-5SK-45WC	1.96E-03	0.998	7.93E-04	0.997	101	2745	4357	5132	5396	5932	6439
HI-SYN-PC-5SK-45WC	1.24E-03	0.988	4.79E-04	0.999	103	2218	3792	4296	4907	4631	5417
HI-SYN-PC-5SK-45WC	9.92E-04	0.985	3.02E-04	0.999	103	2419	3777	4873	5146	5166	5743
HI-VR-SLG-5SK-45WC	9.04E-04	0.976	2.00E-04	0.995	104	854	3175	4936	6015	6795	7363
HI-VR-SLG-5SK-45WC	6.63E-04	0.978	1.85E-04	0.997	104	791	3369	5678	6817	7319	7726
HI-SYN-SLG-5SK-45WC	6.82E-04	0.981	1.28E-04	0.992	102	1230	3892	5965	7006	7520	9003
HI-SYN-SLG-5SK-45WC	5.22E-04	0.972	1.11E-04	0.971	102	945	3249	5024	6114	6730	9144
HI-VR-PC-6SK-50WC	1.33E-03	0.990	7.89E-04	0.993	99	1858	2949	3717	4385	4861	5386
HI-VR-PC-6SK-50WC	8.64E-04	0.976	4.76E-04	0.991	96	1813	2901	3704	4137	4636	5235
HI-SYN-PC-6SK-50WC	2.54E-03	0.994	1.14E-03	0.994	103	1467	2391	3333	3757	4432	4873
HI-SYN-PC-6SK-50WC	1.89E-03	0.994	8.53E-04	0.992	103	1713	3118	3812	4303	5033	5496
HI-VR-SLG-6SK-50WC	9.99E-04	0.989	3.71E-04	0.980	102	1160	2779	4237	5323	6238	6238
HI-VR-SLG-6SK-50WC	1.25E-03	0.984	4.47E-04	0.976	101	1187	3014	4464	5406	6518	6518
HI-VR-PC-5.5SK-52WC	1.37E-03	0.983	5.30E-04	0.985	103	2012	3008	3478	4172	4584	5192
HI-VR-PC-5.5SK-52WC	1.46E-03	0.980	6.29E-04	0.984	103	1882	2978	3771	4178	4751	5455
HI-SYN-PC-5.5SK-52WC	2.14E-03	0.994	9.77E-04	0.991	103	2018	2956	3658	4077	4515	5171
HI-SYN-PC-5.5SK-52WC	2.51E-03	0.992	1.13E-03	0.993	103	1916	2884	3597	4025	4629	5147
HI-VR-SLG-5.5SK-52WC	2.53E-03	0.998	5.75E-04	0.990	102	1200	2788	3947	4962	5691	6354
HI-VR-SLG-5.5SK-52WC	2.41E-03	0.994	4.37E-04	0.875	102	1298	2717	4204	4796	5656	6461
HI-SYN-SLG-5.5SK-52WC	1.32E-03	0.985	3.45E-04	0.992	103	1437	3174	4555	5412	6126	6610
HI-SYN-SLG-5.5SK-52WC	1.45E-03	0.984	3.98E-04	0.994	102	1312	3070	4422	5243	6095	6690

Table 8: Hardened concrete test results for absorptivity, F-T durability, and compressive strength for Phase II low air content mixtures.

Mixture ID	Absorptivity ($mm^2/sec^{1/2}$)				F-T	Compressive Strength (psi)					
	Initial Slope	R	Secondary Slope	R	DF @ 300 Cycles	1 day	3 days	7 days	14 days	28 days	90 days
LO-VR-PC-6SK-45WC	2.52E-03	0.992	9.19E-04	0.994	103	2918	4338	5191	5734	6235	6867
LO-VR-PC-6SK-45WC	2.49E-03	0.992	9.93E-04	0.993	103	2935	4674	5262	5873	5996	6953
LO-SYN-PC-6SK-45WC	2.01E-03	0.994	1.05E-03	0.997	103	2618	4306	5075	5232	5872	6424
LO-SYN-PC-6SK-45WC	1.87E-03	0.993	1.05E-03	0.998	102	2236	3830	4830	5136	5928	6243
LO-VR-SLG-6SK-45WC	6.96E-04	0.956	2.98E-04	0.993	102	1586	4196	5623	6868	7393	8344
LO-VR-SLG-6SK-45WC	1.06E-03	0.983	4.09E-04	0.990	101	1571	3898	5576	6934	7378	8103
LO-SYN-SLG-6SK-45WC	2.99E-03	0.986	8.26E-04	0.987	96	-	-	7128	4915	5486	7794
LO-SYN-SLG-6SK-45WC	2.90E-03	0.992	7.92E-04	0.979	99	-	-	5501	6158	7575	6566
LO-VR-FA-6SK-45WC	1.98E-03	0.976	3.58E-04	0.995	27	3193	4929	5411	6185	6369	7425
LO-VR-FA-6SK-45WC	2.39E-03	0.971	4.26E-04	0.985	35	3114	4771	5480	6019	6318	7140
LO-SYN-FA-6SK-45WC	2.73E-03	0.987	1.10E-03	0.993	81	2980	4540	5200	5731	6165	7223
LO-SYN-FA-6SK-45WC	2.67E-03	0.982	1.02E-03	0.993	97	3091	4557	5183	5838	6147	7150
LO-VR-PC-5SK-45WC	2.30E-03	0.996	1.18E-03	0.998	100	3143	5094	6001	6493	6811	7097
LO-VR-PC-5SK-45WC	2.35E-03	0.998	1.14E-03	0.995	100	2938	5106	5685	6192	6518	7043
LO-SYN-PC-5SK-45WC	4.64E-03	0.994	1.78E-03	0.991	99	1939	2736	5265	5417	5452	5194
LO-SYN-PC-5SK-45WC	2.82E-03	0.984	9.79E-04	0.999	101	2989	5601	6454	6622	7198	7586
LO-VR-SLG-5SK-45WC	1.93E-03	0.994	7.45E-04	0.997	100	1422	4449	6564	7831	8696	9333
LO-VR-SLG-5SK-45WC	1.72E-03	0.992	5.58E-04	0.996	50	1248	4333	7049	8264	9205	9395
LO-SYN-SLG-5SK-45WC	5.93E-04	0.972	6.32E-05	0.935	102	1128	4192	6577	7729	8648	8273
LO-SYN-SLG-5SK-45WC	5.16E-04	0.966	6.94E-05	0.943	100	989	3891	6731	8106	7988	7092
LO-VR-PC-6SK-50WC	2.13E-03	0.996	1.25E-03	0.993	99	2186	3629	4305	4962	5322	6444
LO-VR-PC-6SK-50WC	1.54E-03	0.987	8.88E-04	0.994	100	2038	3264	4211	4360	5158	5699
LO-SYN-PC-6SK-50WC	1.80E-03	0.989	1.07E-03	0.998	103	2170	3784	4530	5170	4951	6641
LO-SYN-PC-6SK-50WC	2.05E-03	0.992	1.18E-03	0.998	102	2014	3807	3874	4884	5224	5995
LO-VR-SLG-6SK-50WC	1.37E-03	0.993	3.86E-04	0.975	101	1172	2914	4523	5703	6669	6669
LO-VR-SLG-6SK-50WC	7.03E-04	0.969	2.26E-04	0.977	100	1074	3030	4380	5661	6293	6293
LO-VR-PC-5.5SK-52WC	9.75E-04	0.969	4.27E-04	0.994	101	2026	3259	4003	4448	5061	6029
LO-VR-PC-5.5SK-52WC	2.84E-03	0.996	1.18E-03	0.998	102	2311	3510	4288	4849	5317	6003
LO-SYN-PC-5.5SK-52WC	2.46E-03	0.995	1.06E-03	0.995	103	2112	3239	3983	4369	4875	5368
LO-SYN-PC-5.5SK-52WC	3.75E-03	0.995	1.72E-03	0.994	103	1988	2998	3877	4083	4708	4949
LO-VR-SLG-5.5SK-52WC	2.55E-03	0.990	4.49E-04	0.991	95	1396	2738	4012	5316	5736	6705
LO-VR-SLG-5.5SK-52WC	2.19E-03	0.994	3.79E-04	0.990	94	1563	3458	4925	5841	6351	7128
LO-SYN-SLG-5.5SK-52WC	1.14E-03	0.983	3.00E-04	0.989	100	2008	2455	3810	4831	5392	7341
LO-SYN-SLG-5.5SK-52WC	1.18E-03	0.982	3.46E-04	0.991	100	2045	2227	3509	4462	6041	7104

Table 9: Hardened concrete test results for absorptivity, F-T durability, and compressive strength for Phase III very low air content mixtures.

Mixture ID	Absorptivity ($mm^2/sec^{1/2}$)				F-T	Compressive Strength (psi)					
	Initial Slope	R	Secondary Slope	R	DF @ 300	1 day	3 days	7 days	14 days	28 days	90 days
VLO-VR-PC-	6.96E-04	0.969	2.27E-04	0.964	96	3098	5140	6240	6543	6957	7314
VLO-SYN-PC-	5.23E-04	0.942	2.13E-04	0.976	96	2781	5743	6626	6973	7340	7895
VLO-VR-SLG-	4.54E-04	0.938	1.22E-04	0.959	78	1464	5402	7050	7983	8687	9647
VLO-SYN-SLG-	3.14E-04	0.884	-	-	64	1125	5074	6926	7988	8749	9636
VLO-VR-FA-	3.24E-04	0.860	6.85E-05	0.912	6	2522	4383	5307	5959	6502	7508
VLO-SYN-FA-	3.28E-04	0.899	8.47E-05	0.912	15	2532	4358	5398	6045	6521	7445
VLO-VR-PC-	5.75E-04	0.890	2.09E-04	0.984	104	2152	4465	6215	6568	7156	7669
VLO-SYN-PC-	6.69E-04	0.940	1.97E-04	0.970	105	1686	5071	6760	7231	7406	8394
VLO-VR-SLG-	6.70E-04	0.959	2.16E-04	0.972	105	766	4931	7102	7778	8674	9600
VLO-SYN-SLG-	5.75E-04	0.968	1.11E-04	0.978	87	822	4195	6694	8381	8604	9461
VLO-VR-FA-	5.79E-04	0.967	1.84E-04	0.985	103	1455	4885	5469	6527	6862	7733
VLO-SYN-FA-	3.93E-04	0.912	-	-	104	1392	4008	5997	6469	7029	8012

Table 10: F-T test results under different freezing regimes for Phase III very low air content mixtures.

Mixture ID	Procedure B *(Freeze in Air)* DF @ 300 cycles	Procedure A *(Freeze in Water)* DF @ 300 cycles	Procedure A *(Freeze in 4.0 wt. % $CaCl_2$ Brine)* DF @ 300 cycles
VLO-VR-PC-6SK-46WC	96	95	97
VLO-SYN-PC-6SK-46WC	96	79	82
VLO-VR-SLG-6SK-46WC	78	52	44
VLO-SYN-SLG-6SK-46WC	64	65	65
VLO-VR-FA-6SK-45WC	6	13	11
VLO-SYN-FA-6SK-46WC	15	20	14
VLO-VR-PC-5.2SK-46WC	104	98	98
VLO-SYN-PC-5.2SK-46WC	105	94	98
VLO-VR-SLG-5.2SK-46WC	105	99	100
VLO-SYN-SLG-5.2SK-46WC	87	98	95
VLO-VR-FA-5.2SK-46WC	103	96	100
VLO-SYN-FA-5.2SK-46WC	104	98	98

Table 11: Maturity test results for Phase II high air content mixtures.

Mixture ID	Temperature-Time Factor (°C-days)							Equivalent Age (days at 20°C)						
	1 d	3 d	7 d	14 d	28 d	Slope $\Delta psi/\Delta log_{10}$ (°C-days)	Inter-cept (psi)	1 d	3 d	7 d	14 d	28 d	Slope $\Delta psi/\Delta log_{10}$ (eq. age)	Inter-cept (psi)
HI-VR-PC-6SK-45WC	24.3	68.5	156.6	310.9	618.5	1860	-235	1.3	3.5	8.0	15.9	31.6	1879	2142
	24.2	68.5	156.7	309.8	615.6	2012	46	1.3	3.5	8.0	15.9	31.4	2033	2618
HI-SYN-PC-6SK-45WC	23.7	68.5	157.6	313.2	624.7	2328	-667	1.2	3.5	8.1	16.1	32.0	2342	2319
	23.9	68.3	157.1	312.0	622.2	2042	-118	1.3	3.5	8.1	16.0	31.9	2059	2496
HI-VR-SLG-6SK-45WC	23.6	68.7	158.4	315.3	629.2	3353	-3227	1.2	3.6	8.2	16.2	32.3	3378	1063
	23.0	67.8	156.9	312.3	622.8	3367	-3016	1.2	3.5	8.1	16.0	31.9	3386	1304
HI-SYN-SLG-6SK-45WC	23.3	71.7	161.9	320.5	643.4	2608	-162	1.2	3.8	8.4	16.6	33.3	2611	3188
	23.0	71.4	161.9	321.4	645.2	2380	194	1.2	3.7	8.4	16.6	33.4	2380	3254
HI-VR-FA-6SK-45WC	30.6	78.1	170.6	332.4	657.2	1857	59	1.8	4.3	9.1	17.5	34.4	1932	2334
	30.0	77.1	169.0	330.0	652.1	1877	-265	1.8	4.2	9.0	17.3	34.0	1956	2035
HI-SYN-FA-6SK-45WC	31.3	80.8	172.9	337.4	651.1	1346	-102	1.9	4.5	9.3	17.9	34.0	1416	1526
	30.6	79.6	170.8	333.8	644.2	1482	-279	1.8	4.4	9.1	17.6	33.5	1552	1526
HI-VR-PC-5SK-45WC	28.9	75.0	169.2	327.5	638.8	2152	-564	1.7	4.1	9.0	17.1	33.1	2225	2100
	28.5	74.8	169.1	327.6	638.1	2265	-214	1.7	4.0	9.0	17.1	33.0	2340	2592
HI-SYN-PC-5SK-45WC	26.9	71.5	160.1	315.5	633.9	1809	66	1.5	3.8	8.3	16.3	32.7	1844	2347
	27.1	71.7	160.4	316.3	634.0	2081	-217	1.5	3.8	8.3	16.3	32.7	2127	2401
HI-VR-SLG-5SK-45WC	25.8	70.5	159.5	315.3	632.8	4339	-4985	1.4	3.7	8.3	16.2	32.6	4411	512
	25.2	69.7	158.8	314.6	631.7	4848	-5622	1.4	3.6	8.2	16.2	32.6	4914	539
HI-SYN-SLG-5SK-45WC	24.6	69.7	159.3	316.3	640.1	4574	-4705	1.3	3.6	8.2	16.3	33.1	4613	1133
	24.3	69.3	158.6	314.9	635.8	4184	-4565	1.3	3.6	8.2	16.2	32.8	4217	783
HI-VR-PC-6SK-50WC	24.3	68.8	157.3	313.8	624.7	2149	-1051	1.3	3.6	8.1	16.1	32.0	2168	1699
	24.1	68.8	157.4	313.8	626.2	1992	-829	1.3	3.6	8.1	16.1	32.1	2009	1720
HI-SYN-PC-6SK-50WC	23.1	67.3	155.9	309.2	619.1	2080	-1362	1.2	3.5	8.0	15.8	31.7	2094	1307
	23.2	67.4	155.8	309.3	619.3	2249	-1204						2264	1681
HI-VR-SLG-6SK-50WC	23.8	68.5	157.9	312.8	625.5	3633	-3829	1.3	3.5	8.1	16.0	32.1	3662	821
	22.9	67.0	155.4	309.1	620.1	3709	-3789	1.2	3.4	8.0	15.8	31.7	3727	977
HI-VR-PC-5.5SK-52WC	28.7	75.2	165.2	320.3	632.2	1910	-697	1.7	4.1	8.7	16.6	32.6	1978	1670
	28.3	74.7	164.3	318.9	629.3	2106	-1055	1.6	4.0	8.6	16.5	32.4	2178	1560
HI-SYN-PC-5.5SK-52WC	29.1	74.4	162.6	322.3	648.0	1849	-574	1.7	4.0	8.5	16.8	33.7	1915	1714
	28.2	73.1	160.7	319.4	642.3	1968	-854	1.6	3.9	8.4	16.6	33.3	2030	1596
HI-VR-SLG-5.5SK-52WC	26.4	70.9	161.4	315.1	624.1	3300	-3394	1.4	3.7	8.4	16.2	32.0	3367	774
	26.1	70.8	161.1	314.9	623.1	3193	-3141	1.4	3.7	8.4	16.2	32.0	3257	892
HI-SYN-SLG-5.5SK-52WC	26.6	74.3	168.8	331.2	650.9	3418	-3282	1.5	4.0	8.9	17.3	33.8	3478	1025
	26.6	74.3	169.2	331.8	649.7	3451	-3465	1.5	4.0	8.9	17.4	33.7	3514	879

Table 12: Maturity test results for Phase II low air content mixtures.

Mixture ID	Temperature-Time Factor (°C-days)							Equivalent Age (days at 20°C)						
	1 d	3 d	7 d	14 d	28 d	Slope $\Delta psi/\Delta log_{10}$ (°C-days)	Inter-cept (psi)	1 d	3 d	7 d	14 d	28 d	Slope $\Delta psi/\Delta log_{10}$ (eq. age)	Inter-cept (psi)
LO-VR-PC-6SK-45WC	24.3	69.5	160.3	318.8	636.6	2326	-112	1.3	3.6	8.3	16.4	32.8	2342	2862
	24.4	69.9	161.2	319.0	636.1	2152	322	1.3	3.6	8.4	16.5	32.8	2170	3070
LO-SYN-PC-6SK-45WC	23.5	67.9	156.7	311.8	621.9	2171	-18	1.2	3.5	8.0	16.0	31.8	2184	2766
	23.8	68.2	156.9	311.8	622.2	2523	-1005	1.3	3.5	8.1	16.0	31.9	2541	2229
LO-VR-SLG-6SK-45WC	23.3	68.7	158.6	316.0	633.4	4109	-3665	1.2	3.6	8.2	16.3	32.6	4131	1600
	23.7	69.1	158.7	315.3	630.0	4223	-3976	1.3	3.6	8.2	16.2	32.4	4259	1420
LO-SYN-SLG-6SK-45WC	23.8	74.5	167.3	330.6	652.9	-2777	12839	1.2	4.0	8.8	17.3	33.9	-2797	9302
	23.8	74.7	167.8	331.4	653.4	3512	-2439	1.2	4.0	8.8	17.3	34.0	3538	2030
LO-VR-FA-6SK-45WC	30.6	78.7	172.0	334.7	663.1	2347	71	1.8	4.4	9.2	17.7	34.8	2446	2937
	31.4	79.1	171.9	334.1	660.6	2382	-87	1.9	4.4	9.2	17.6	34.6	2493	2808
LO-SYN-FA-6SK-45WC	31.5	81.2	173.3	336.9	655.8	2360	-265	1.9	4.6	9.3	17.8	34.3	2479	2592
	32.1	81.6	173.3	336.4	651.6	2322	-144	2.0	4.6	9.4	17.8	34.0	2452	2650
LO-VR-PC-5SK-45WC	28.7	75.7	170.5	329.4	644.2	2678	-328	1.7	4.1	9.1	17.3	33.4	2768	2985
	29.3	75.8	170.5	329.5	642.7	2550	-273	1.7	4.1	9.1	17.3	33.4	2642	2871
LO-SYN-PC-5SK-45WC	26.5	71.7	164.4	323.9	636.2	2896	-2098	1.5	3.8	8.6	16.8	32.8	2953	1552
	26.8	71.9	164.2	323.3	633.3	2867	-427	1.5	3.8	8.6	16.8	32.6	2923	3185
LO-VR-SLG-5SK-45WC	27.9	74.0	162.9	318.1	630.2	5433	-5974	1.6	4.0	8.5	16.4	32.4	5582	826
	27.3	73.0	161.5	316.3	626.4	5985	-6914	1.5	3.9	8.4	16.3	32.2	6136	600
LO-SYN-SLG-5SK-45WC	24.3	70.0	159.8	317.1	642.6	5381	-5907	1.3	3.6	8.3	16.3	33.2	5424	963
	24.8	69.7	158.6	314.4	636.2	5344	-5936	1.3	3.6	8.2	16.2	32.8	5399	876
LO-VR-PC-6SK-50WC	24.0	68.2	155.8	308.7	613.0	2223	-669	1.3	3.5	8.0	15.8	31.3	2243	2178
	24.1	68.5	156.6	311.3	620.0	2134	-760	1.3	3.5	8.0	15.9	31.7	2153	1971
LO-SYN-PC-6SK-50WC	23.8	67.5	156.2	310.7	620.7	2051	-262	1.3	3.5	8.0	15.9	31.8	2067	2364
	23.7	67.2	155.9	310.8	620.5	2170	-674	1.2	3.5	8.0	15.9	31.8	2188	2104
LO-VR-SLG-6SK-50WC	23.1	67.8	157.1	311.8	624.0	3914	-4163	1.2	3.5	8.1	16.0	32.0	3938	856
	23.6	68.5	157.9	312.5	624.2	3755	-3947	1.2	3.5	8.1	16.0	32.0	3787	857
LO-VR-PC-5.5SK-52WC	28.6	75.3	164.9	319.5	631.8	2211	-1040	1.7	4.1	8.7	16.6	32.6	2290	1699
	28.9	75.5	165.1	319.8	631.6	2245	-823	1.7	4.1	8.7	16.6	32.6	2331	1951
LO-SYN-PC-5.5SK-52WC	29.1	74.6	163.0	323.1	651.4	2015	-665	1.7	4.0	8.6	16.8	33.9	2083	1832
	29.8	74.4	161.7	320.7	646.1	1990	-796	1.8	4.0	8.5	16.7	33.6	2067	1659
LO-VR-SLG-5.5SK-52WC	26.4	71.4	162.1	316.6	627.5	3318	-3316	1.5	3.8	8.4	16.3	32.2	3389	868
	26.7	71.6	162.0	316.5	626.6	3575	-3286	1.5	3.8	8.4	16.3	32.2	3656	1214
LO-SYN-SLG-5.5SK-52WC	26.2	71.4	165.3	328.0	648.4	2624	-1979	1.4	3.8	8.6	17.1	33.6	2667	1338
	26.3	71.7	165.8	328.8	647.5	2893	-2607	1.4	3.8	8.7	17.1	33.6	2947	1042

Table 13: F-T test results under different freezing regimes for extended F-T cycling on selected Phase II concrete mixtures.

Mixture ID	Procedure A *(Freeze in Water)*		Procedure A *(Freeze in 4.0 wt. % $CaCl_2$ Brine)*		Procedure A *(Freeze in 4.2 wt. % NaCl Brine)*	
	DF @ 300 cycles	% Dilation @ 100 cycles	DF @ 300 cycles	% Dilation @ 100 cycles	DF @ 300 cycles	% Dilation @ 100 cycles
HI-VR-PC-6SK-45WC	96	0.022	102	0.034	102	0.036
HI-VR-PC-5SK-45WC	97	0.009	98	0.007	100	0.043
LO-VR-PC-6SK-45WC	98	0.005	87	0.014	48	0.013
LO-VR-PC-5SK-45WC	94	0.011	97	0.036	99	0.012
LO-VR-PC-6SK-50WC	*	*	37	-	34	0.133
LO-VR-PC-5.5SK-52WC	23	-	7	-	8	-

* No beams were tested.

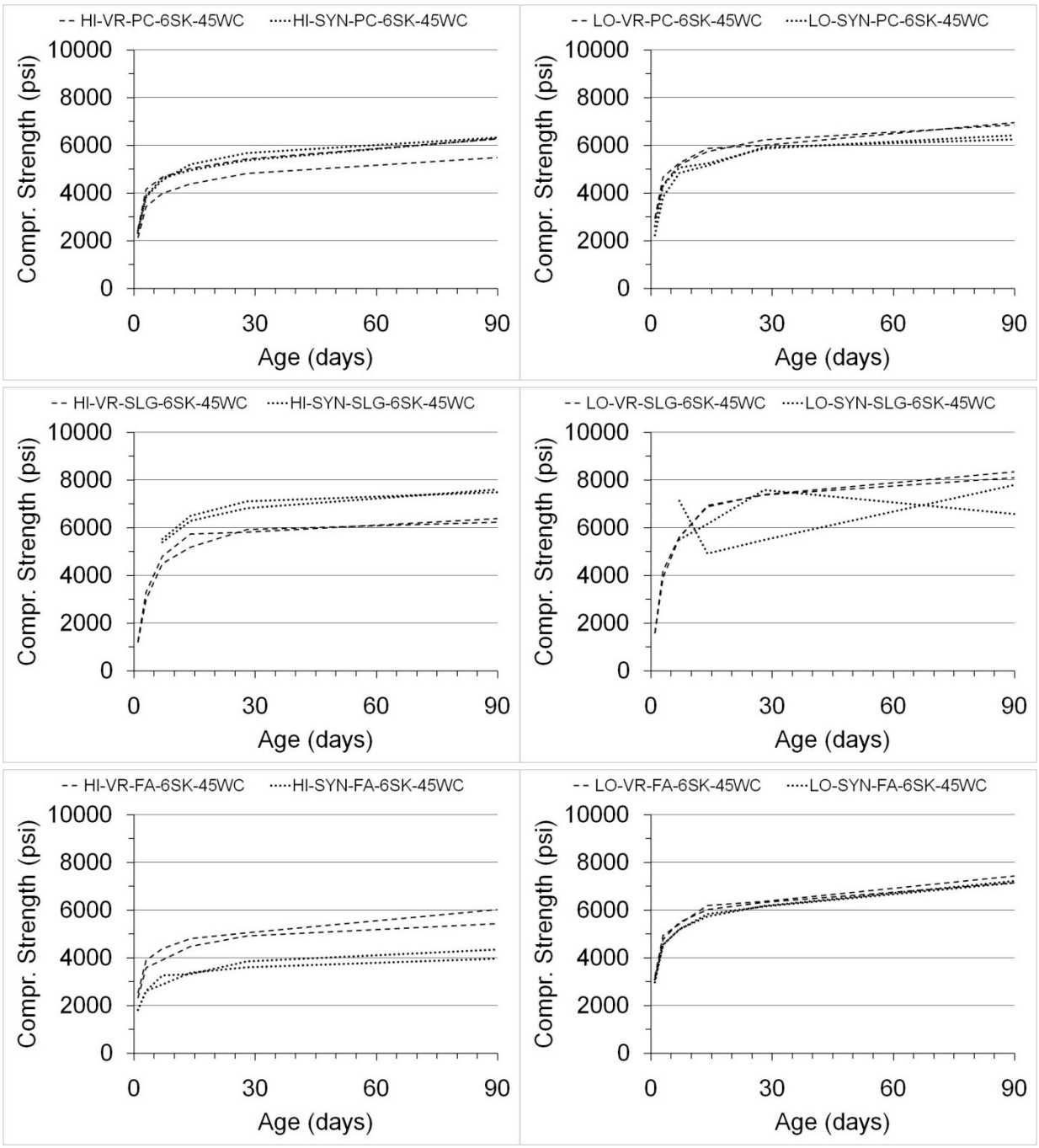

Figure 20: Compressive strength gain plots for the 0.45 *w/cm* 564 lbs/yd^3 CMC mixtures. From left to right, high air content mixtures vs. low air content mixtures. From top to bottom: straight portland cement mixtures, 40 wt. % substitution slag cement mixtures, and 25 wt. % substitution fly ash mixtures. Dashed lines denote mixtures with vinsol resin AEA; dotted lines denote mixtures with synthetic AEA.

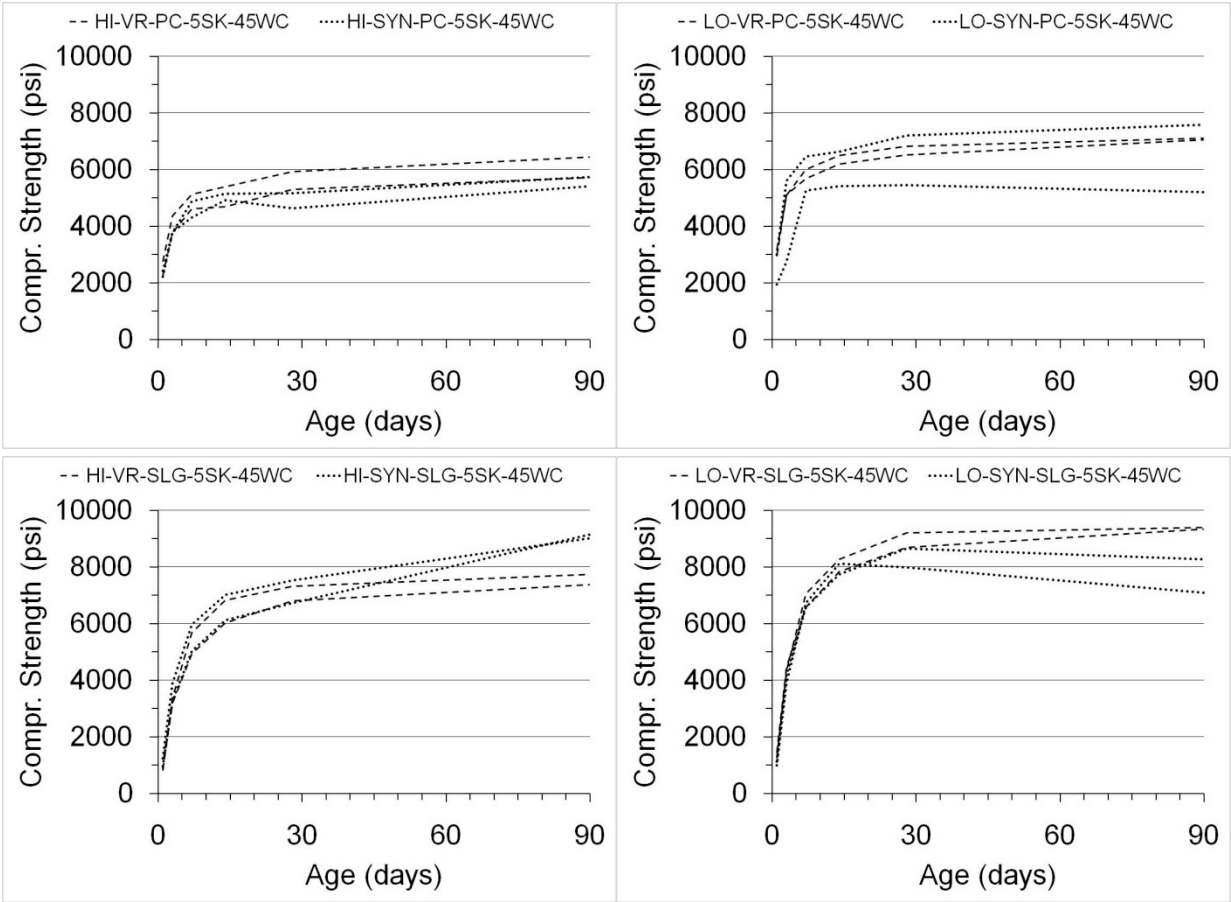

Figure 21: Compressive strength gain plots for the 0.45 *w/cm* 470 lbs/yd^3 CMC mixtures. From left to right, high air content mixtures vs. low air content mixtures. From top to bottom: straight portland cement mixtures, and 40 wt. % substitution slag cement mixtures. Dashed lines denote mixtures with vinsol resin AEA; dotted lines denote mixtures with synthetic AEA.

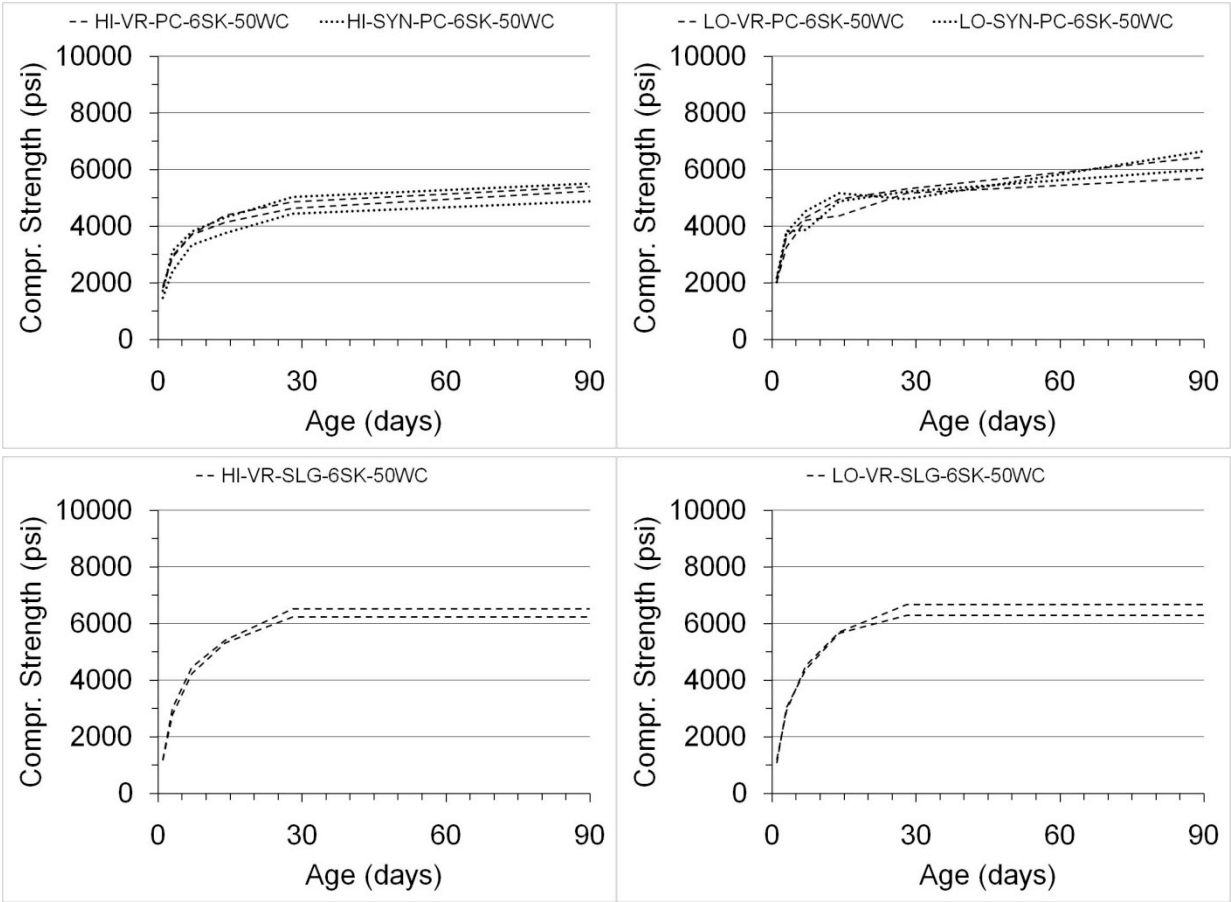

Figure 22: Compressive strength gain plots for the 0.50 *w/cm* 564 lbs/yd^3 CMC mixtures. From left to right, high air content mixtures vs. low air content mixtures. From top to bottom: straight portland cement mixtures, and 40 wt. % substitution slag cement mixtures. Dashed lines denote mixtures with vinsol resin AEA; dotted lines denote mixtures with synthetic AEA.

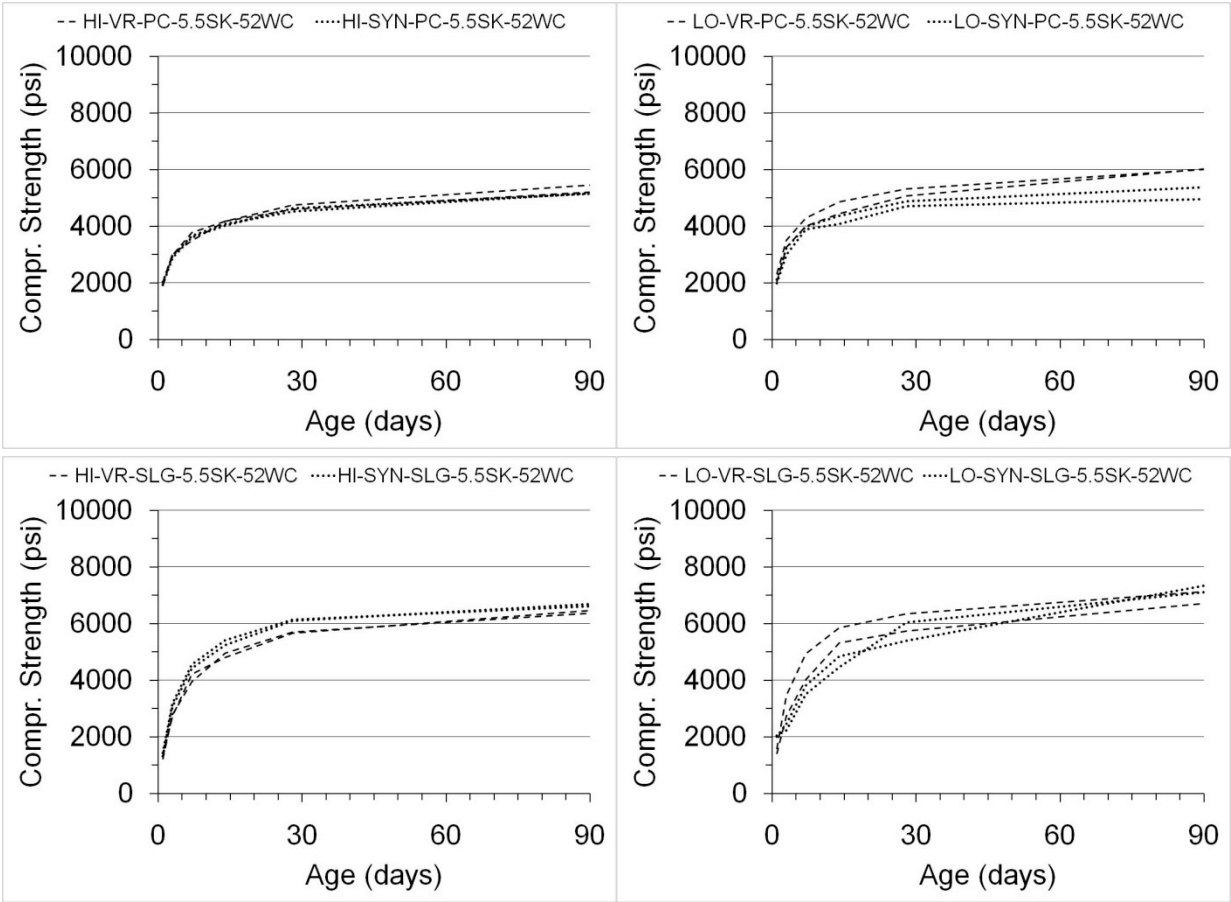

Figure 23: Compressive strength gain plots for the 0.52 *w/cm* 517 lbs/yd^3 CMC mixtures. From left to right, high air content mixtures vs. low air content mixtures. From top to bottom: straight portland cement mixtures, and 40 wt. % substitution slag cement mixtures. Dashed lines denote mixtures with vinsol resin AEA; dotted lines denote mixtures with synthetic AEA.

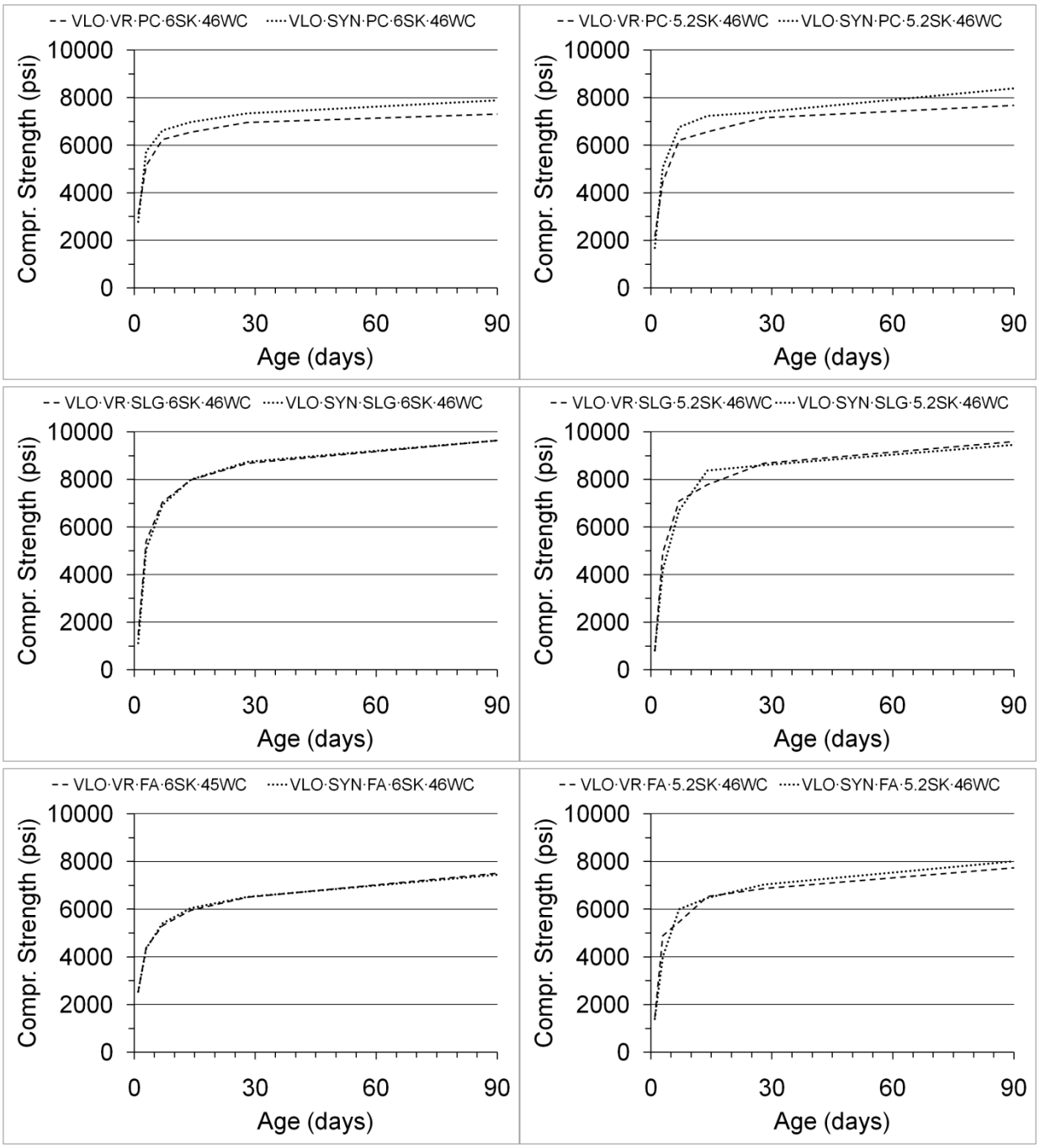

Figure 24: Compressive strength gain plots for the Phase III very low air content 0.46 *w/cm* mixtures. From left to right, 564 lbs/yd^3 CMC mixtures vs. 490 lbs/yd^3 CMC mixtures. From top to bottom: straight portland cement mixtures, 40 wt. % substitution slag cement mixtures, and 25 wt. % substitution fly ash mixtures. Dashed lines denote mixtures with vinsol resin AEA; dotted lines denote mixtures with synthetic AEA.

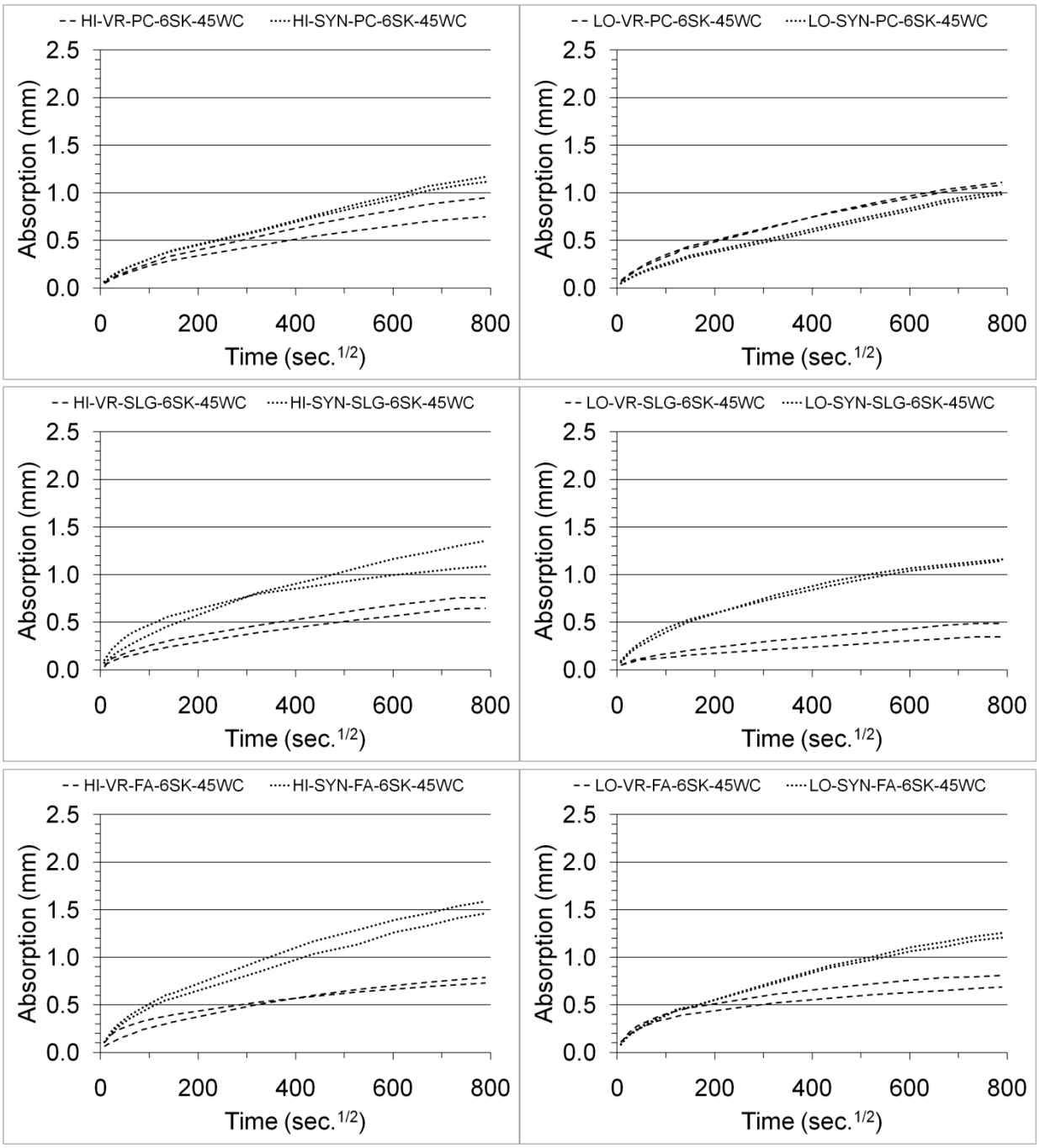

Figure 25: Absorptivity plots for the 0.45 *w/cm* 564 lbs/yd^3 CMC mixtures. From left to right, high air content mixtures vs. low air content mixtures. From top to bottom: straight portland cement mixtures, 40 wt. % substitution slag cement mixtures, and 25 wt. % substitution fly ash mixtures. Dashed lines denote mixtures with vinsol resin AEA; dotted lines denote mixtures with synthetic AEA.

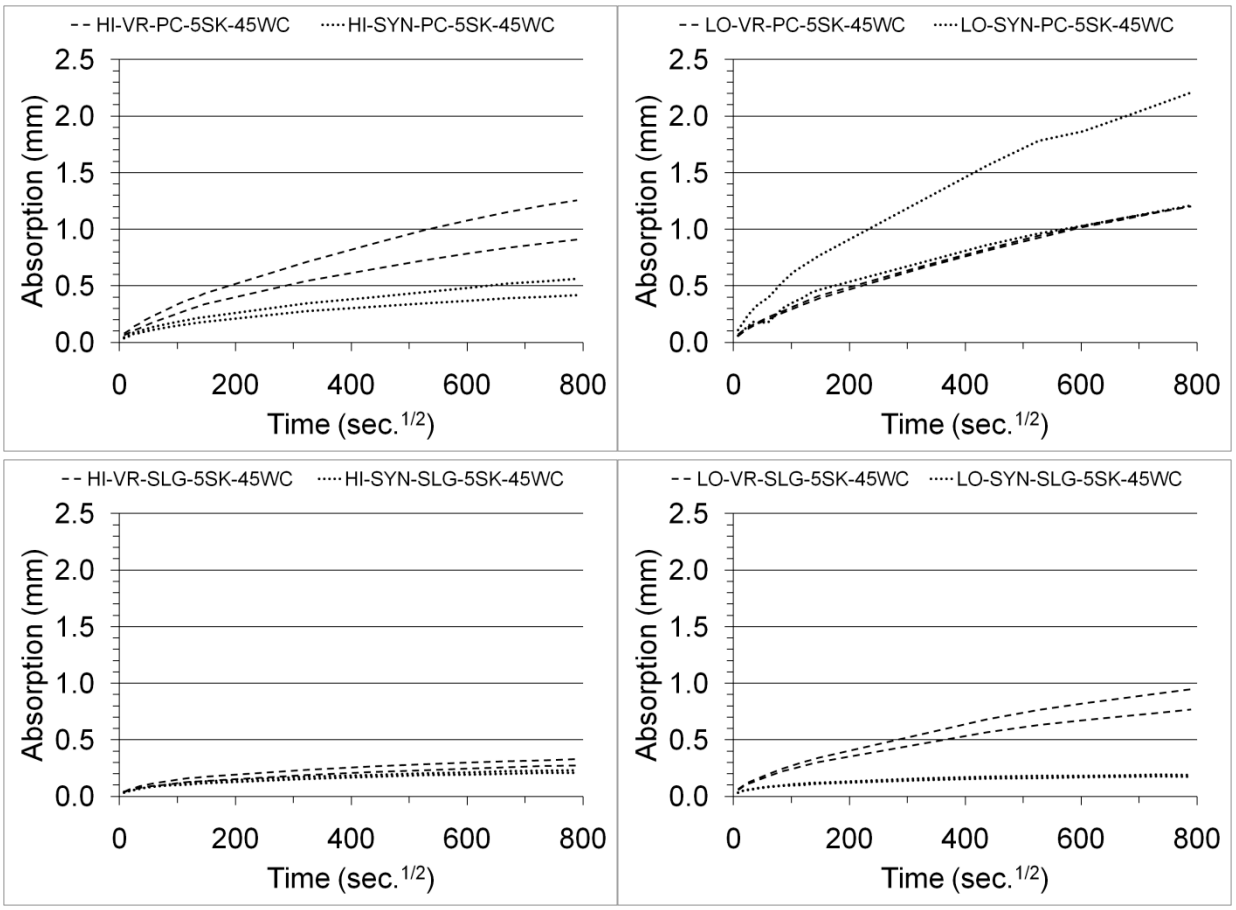

Figure 26: Absorptivity plots for the 0.45 *w/cm* 470 lbs/yd^3 CMC mixtures. From left to right, high air content mixtures vs. low air content mixtures. From top to bottom: straight portland cement mixtures, and 40 wt. % substitution slag cement mixtures. Dashed lines denote mixtures with vinsol resin AEA; dotted lines denote mixtures with synthetic AEA.

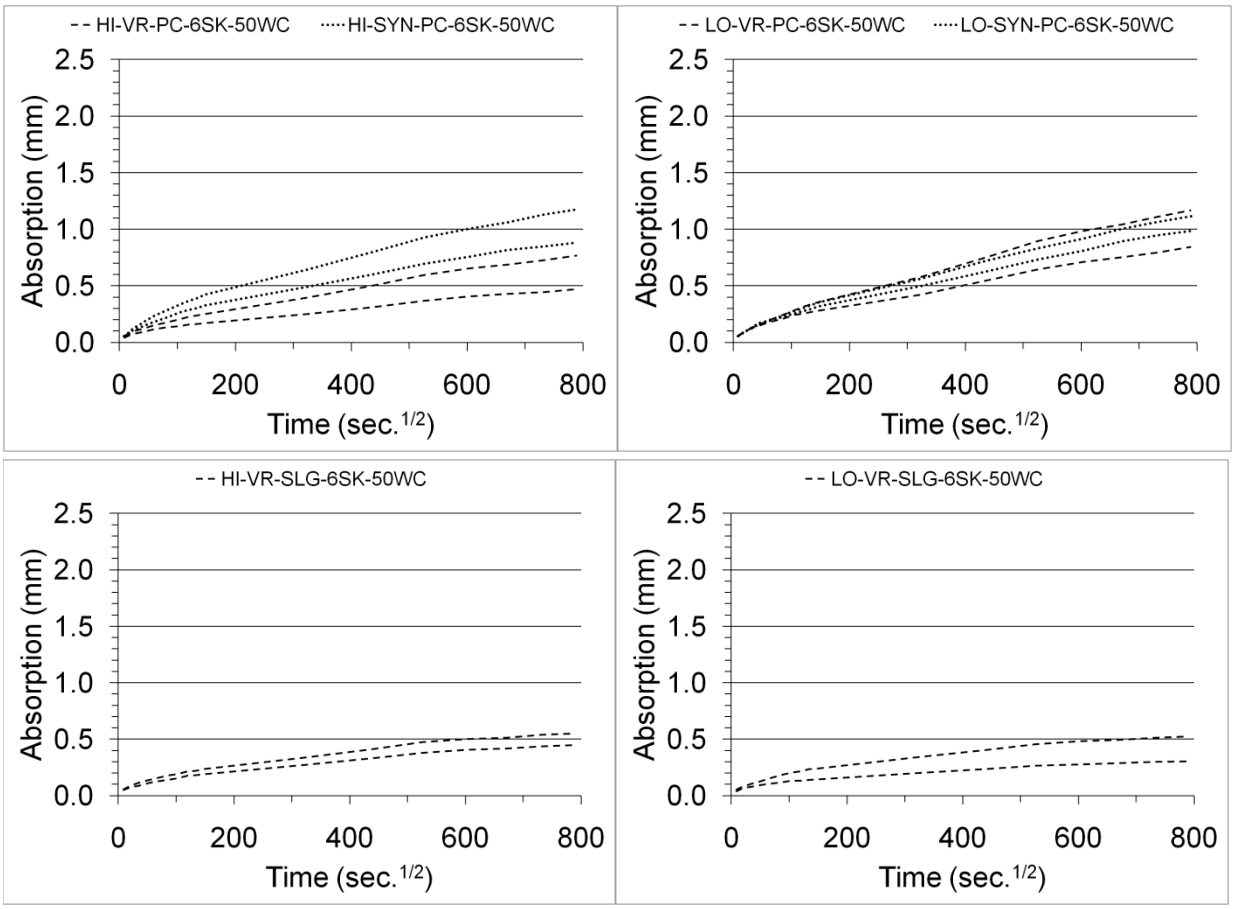

Figure 27: Absorptivity plots for the 0.50 *w/cm* 564 lbs/yd^3 CMC mixtures. From left to right, high air content mixtures vs. low air content mixtures. From top to bottom: straight portland cement mixtures, and 40 wt. % substitution slag cement mixtures. Dashed lines denote mixtures with vinsol resin AEA; dotted lines denote mixtures with synthetic AEA.

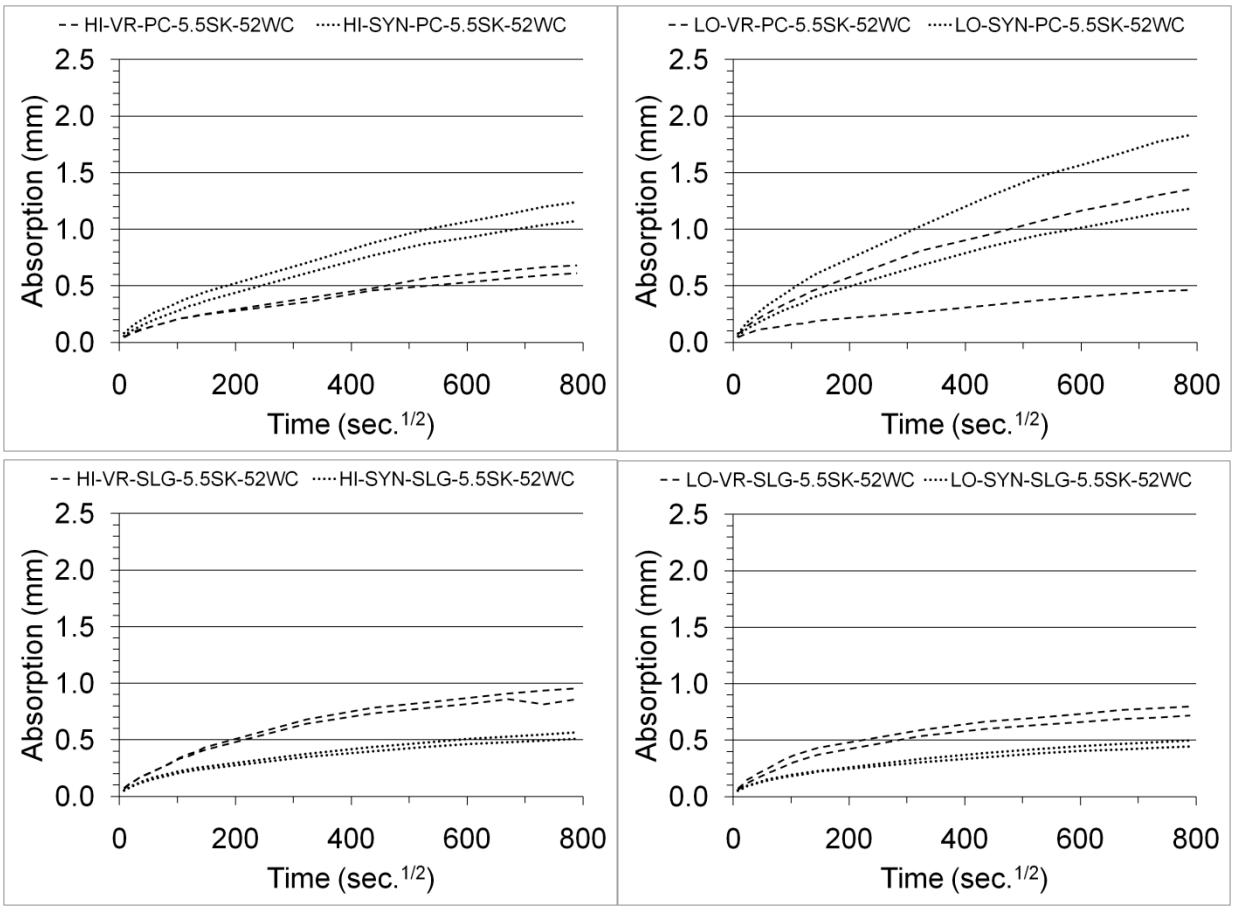

Figure 28: Absorptivity plots for the 0.52 *w/cm* 517 lbs/yd^3 CMC mixtures. From left to right, high air content mixtures vs. low air content mixtures. From top to bottom: straight portland cement mixtures, and 40 wt. % substitution slag cement mixtures. Dashed lines denote mixtures with vinsol resin AEA; dotted lines denote mixtures with synthetic AEA.

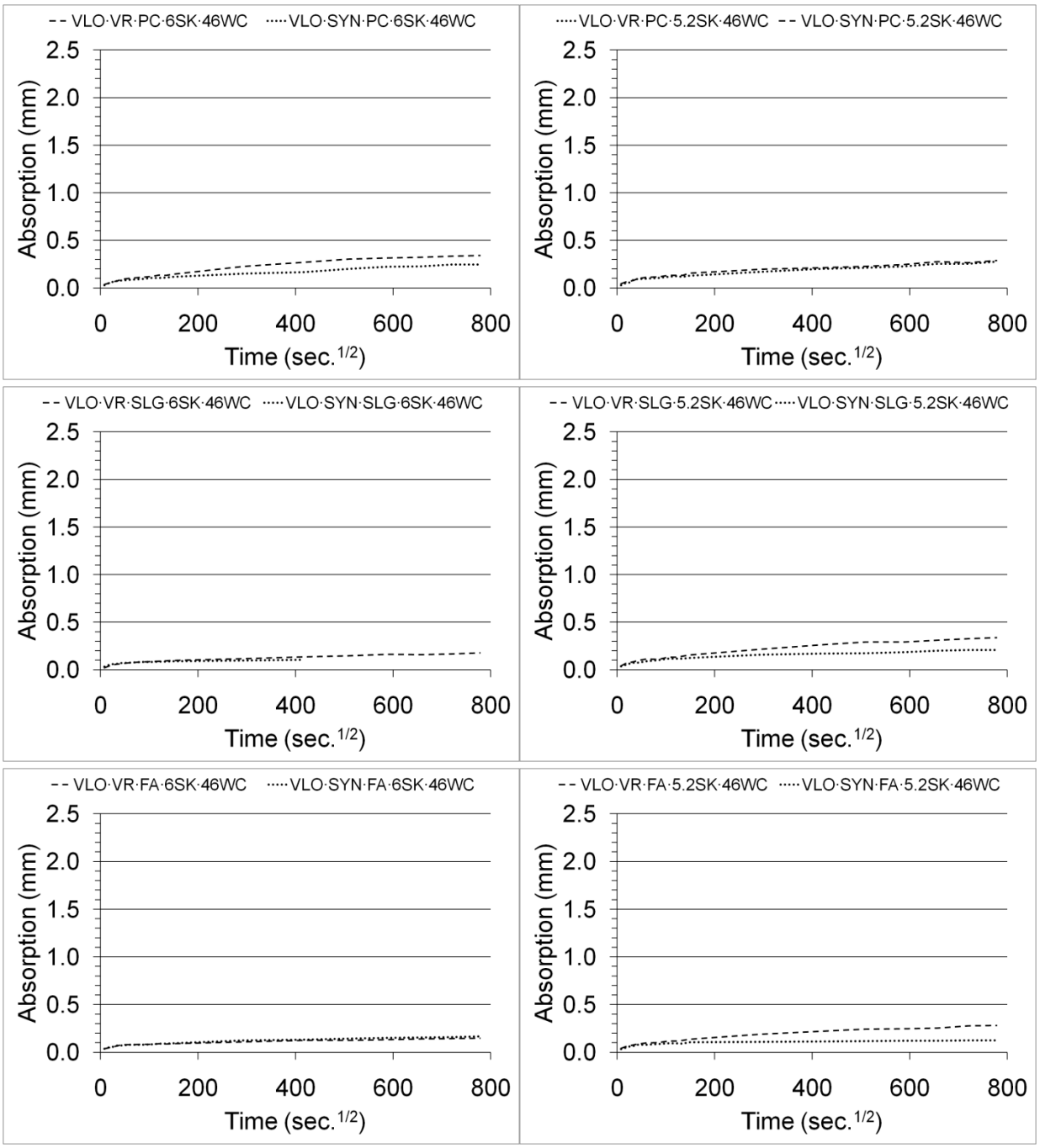

Figure 29: Absorptivity plots for the Phase III very low air content 0.46 *w/cm* mixtures. From left to right, 564 lbs/yd^3 CMC mixtures vs. 490 lbs/yd^3 CMC mixtures. From top to bottom: straight portland cement mixtures, 40 wt. % substitution slag cement mixtures, and 25 wt. % substitution fly ash mixtures. Dashed lines denote mixtures with vinsol resin AEA; dotted lines denote mixtures with synthetic AEA.

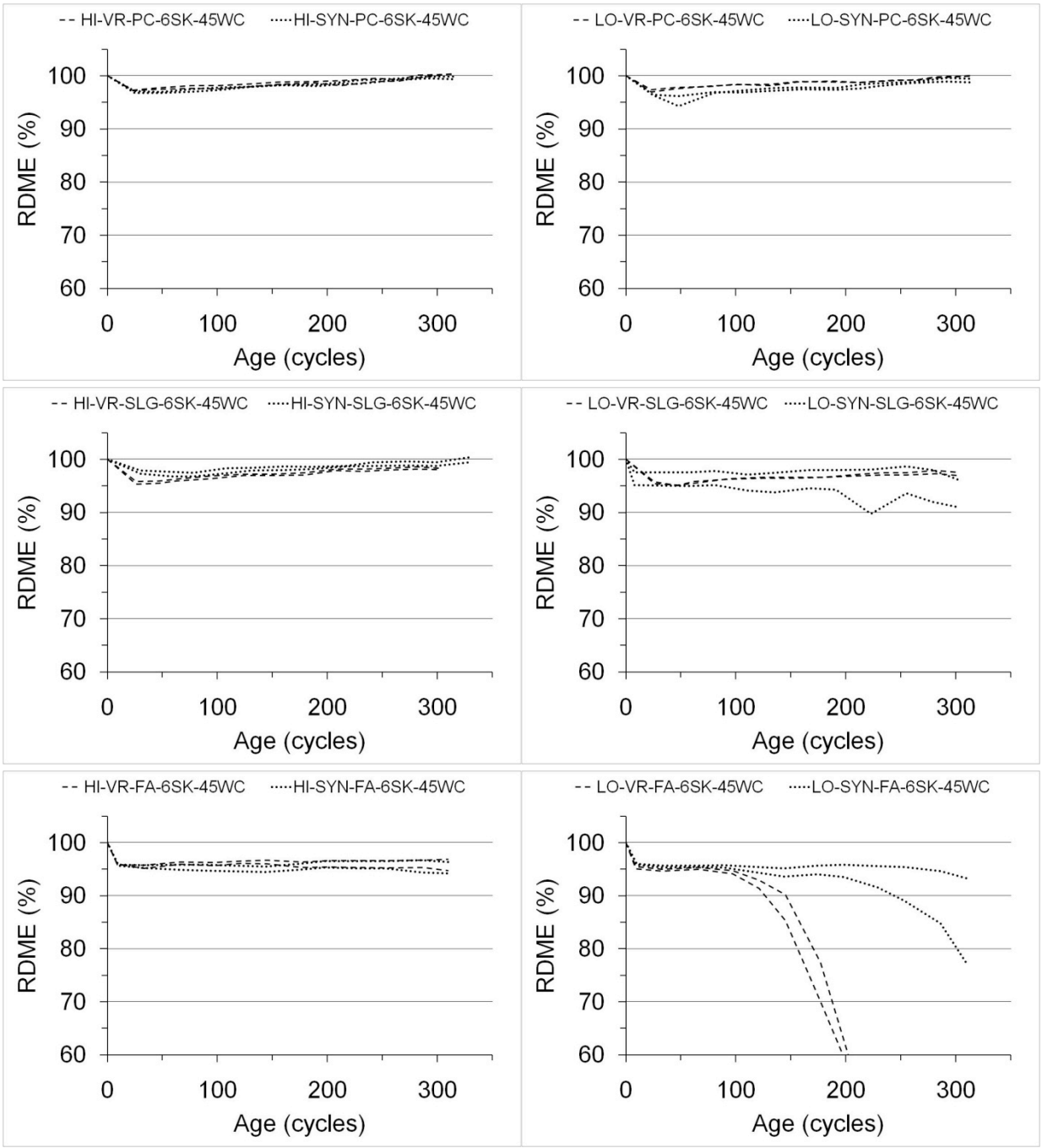

Figure 30: Relative dynamic modulus of elasticity plots for the 0.45 *w/cm* 564 lbs/yd^3 CMC mixtures frozen in air (ASTM C666 Procedure B). From left to right, high air content mixtures vs. low air content mixtures. From top to bottom: straight portland cement mixtures, 40 wt. % substitution slag cement mixtures, and 25 wt. % substitution fly ash mixtures. Dashed lines denote mixtures with vinsol resin AEA; dotted lines denote mixtures with synthetic AEA.

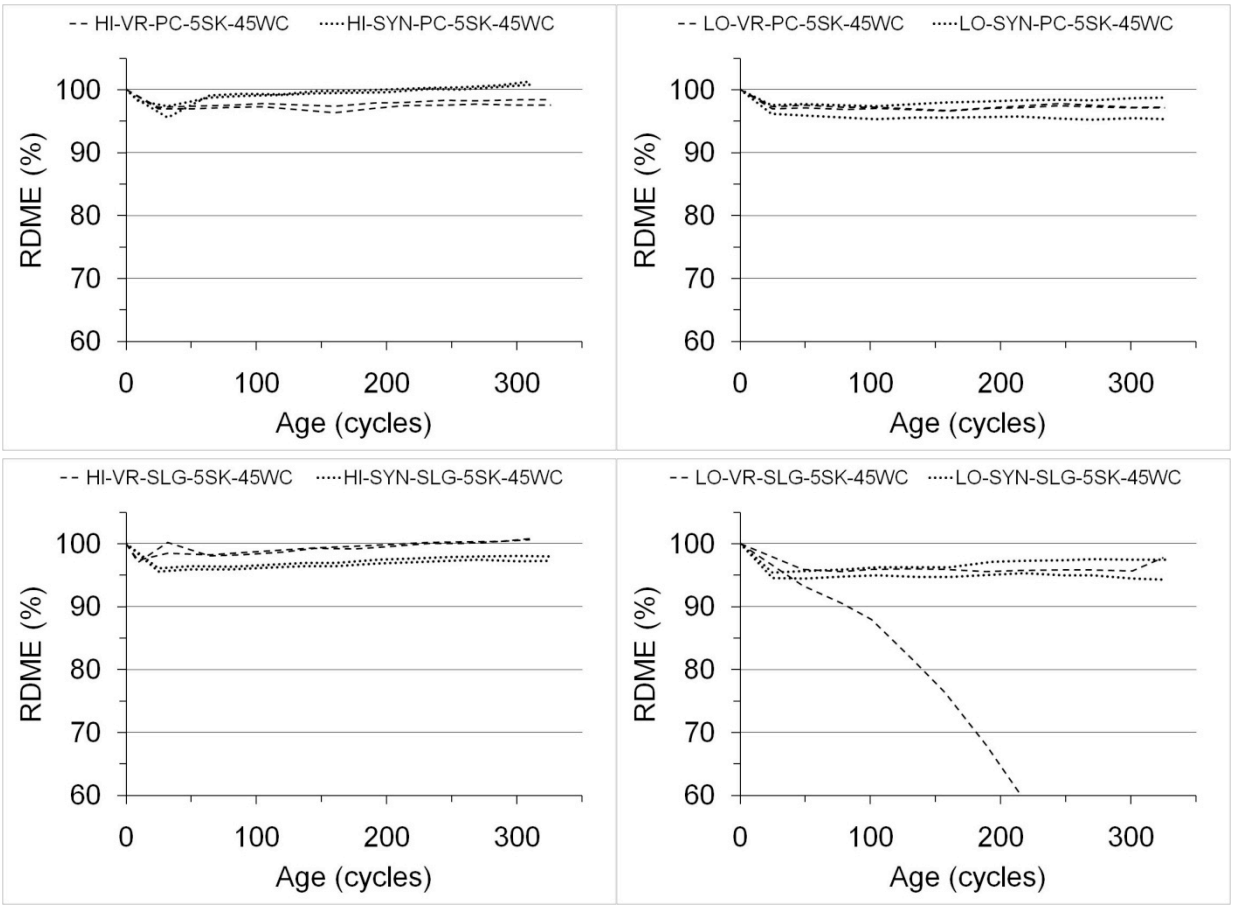

Figure 31: Relative dynamic modulus of elasticity plots for the 0.45 *w/cm* 470 lbs/yd^3 CMC mixtures frozen in air (ASTM C666 Procedure B). From left to right, high air content mixtures vs. low air content mixtures. From top to bottom: straight portland cement mixtures, and 40 wt. % substitution slag cement mixtures. Dashed lines denote mixtures with vinsol resin AEA; dotted lines denote mixtures with synthetic AEA.

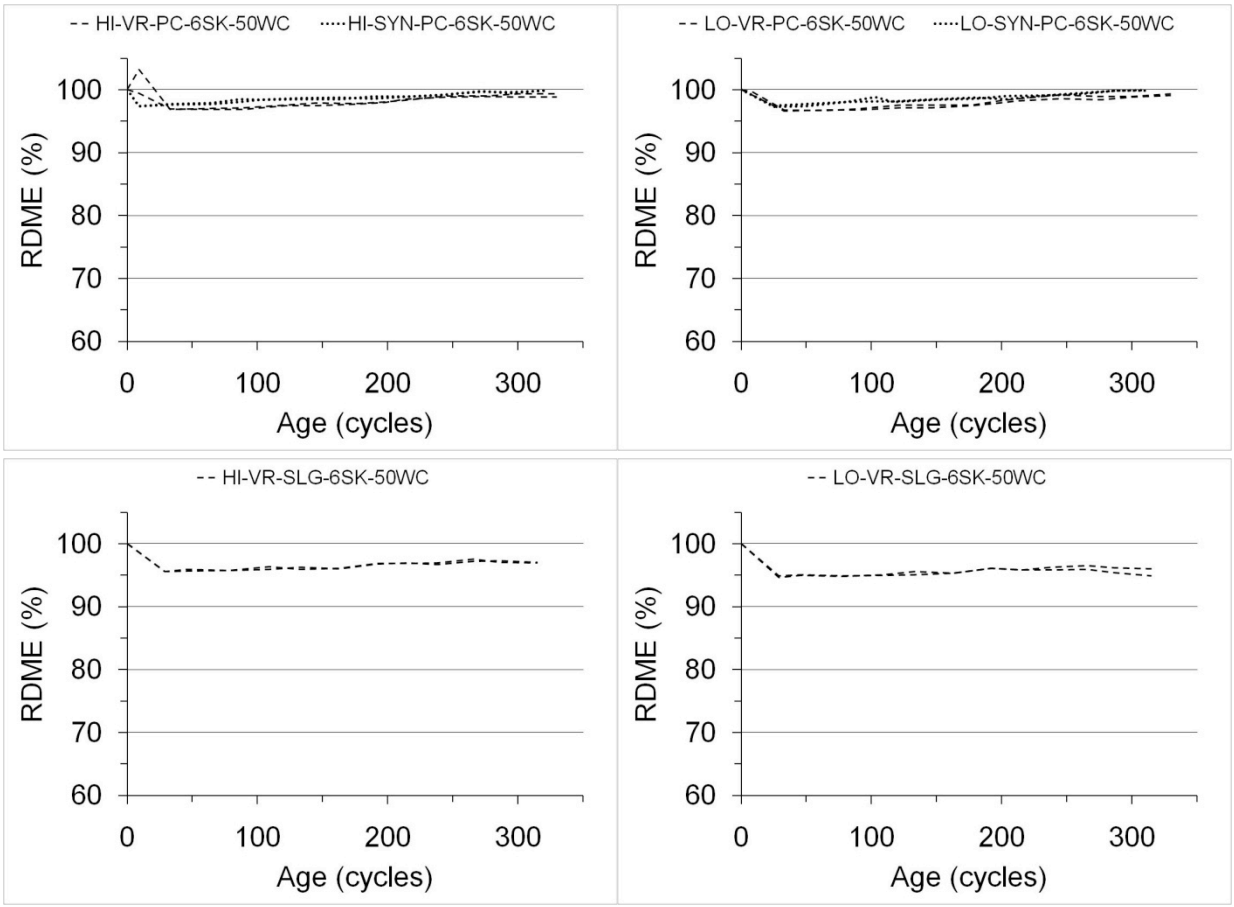

Figure 32: Relative dynamic modulus of elasticity plots for the 0.50 *w/cm* 564 lbs/yd^3 CMC mixtures frozen in air (ASTM C666 Procedure B). From left to right, high air content mixtures vs. low air content mixtures. From top to bottom: straight portland cement mixtures, and 40 wt. % substitution slag cement mixtures. Dashed lines denote mixtures with vinsol resin AEA; dotted lines denote mixtures with synthetic AEA.

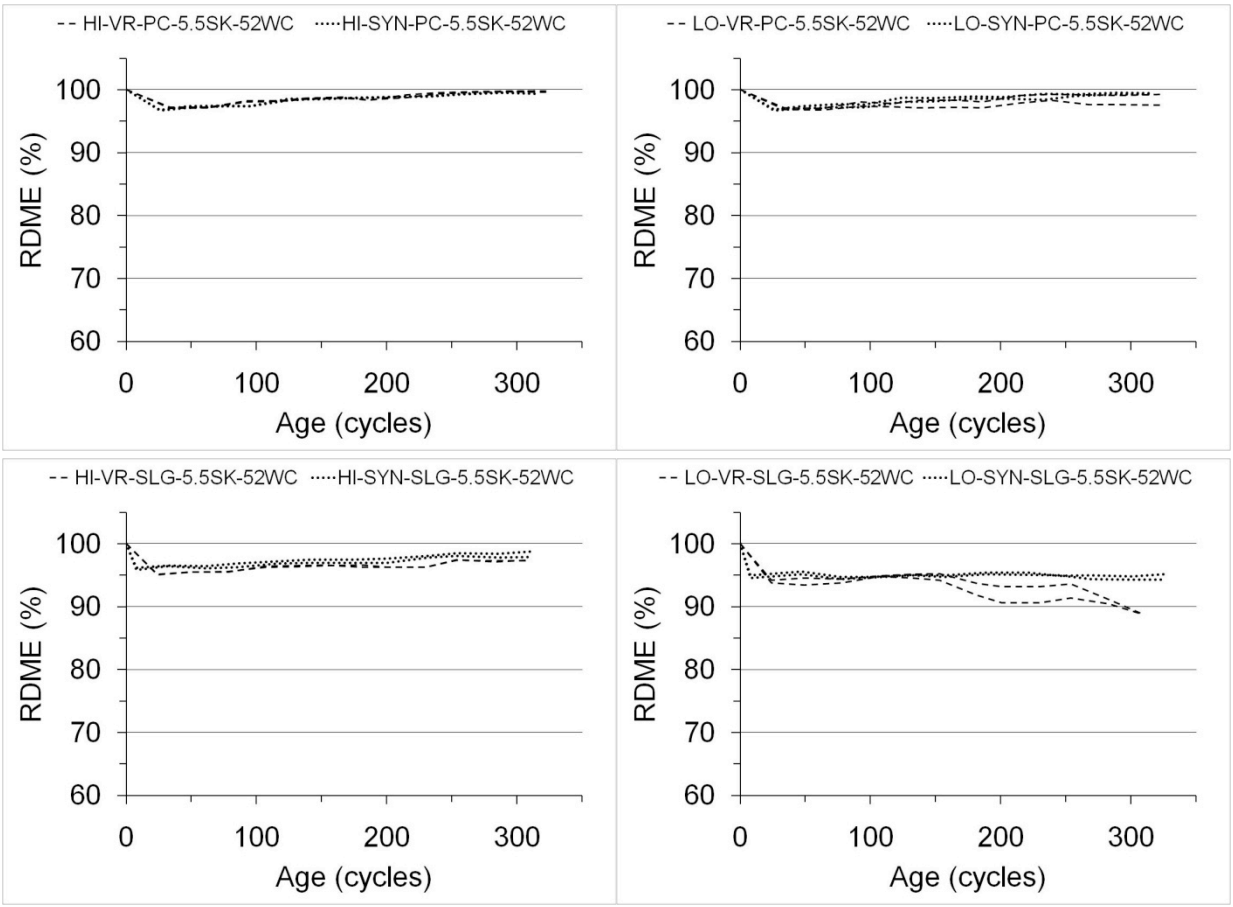

Figure 33: Relative dynamic modulus of elasticity plots for the 0.52 *w/cm* 517 lbs/yd^3 CMC mixtures frozen in air (ASTM C666 Procedure B). From left to right, high air content mixtures vs. low air content mixtures. From top to bottom: straight portland cement mixtures, and 40 wt. % substitution slag cement mixtures. Dashed lines denote mixtures with vinsol resin AEA; dotted lines denote mixtures with synthetic AEA.

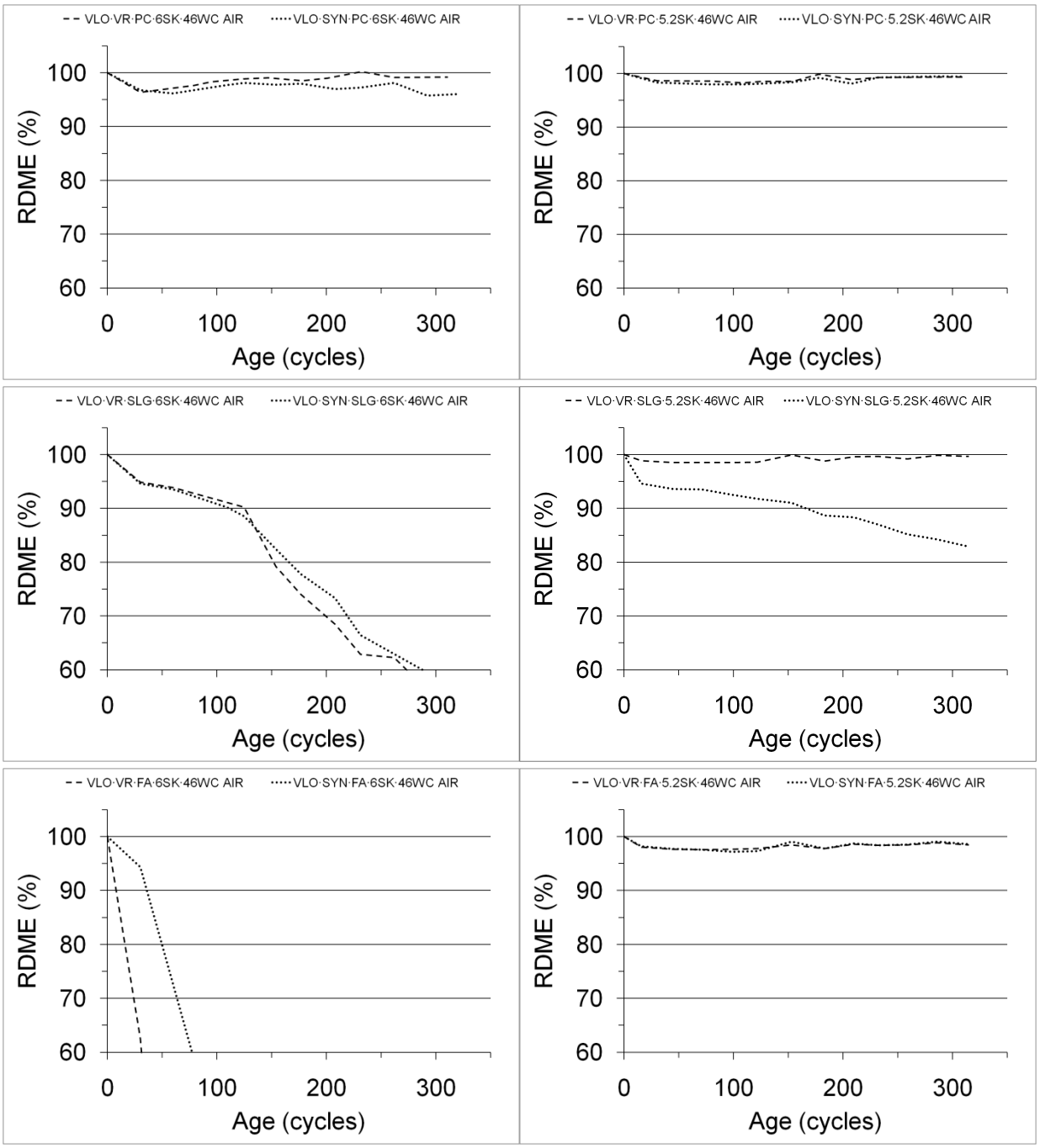

Figure 34: Relative dynamic modulus of elasticity plots for the Phase III very low air content 0.46 *w/cm* mixtures frozen in air (ASTM C666 Procedure B). From left to right, 564 lbs/yd^3 CMC mixtures vs. 490 lbs/yd^3 CMC mixtures. From top to bottom: straight portland cement mixtures, 40 wt. % substitution slag cement mixtures, and 25 wt. % substitution fly ash mixtures. Dashed lines denote mixtures with vinsol resin AEA; dotted lines denote mixtures with synthetic AEA.

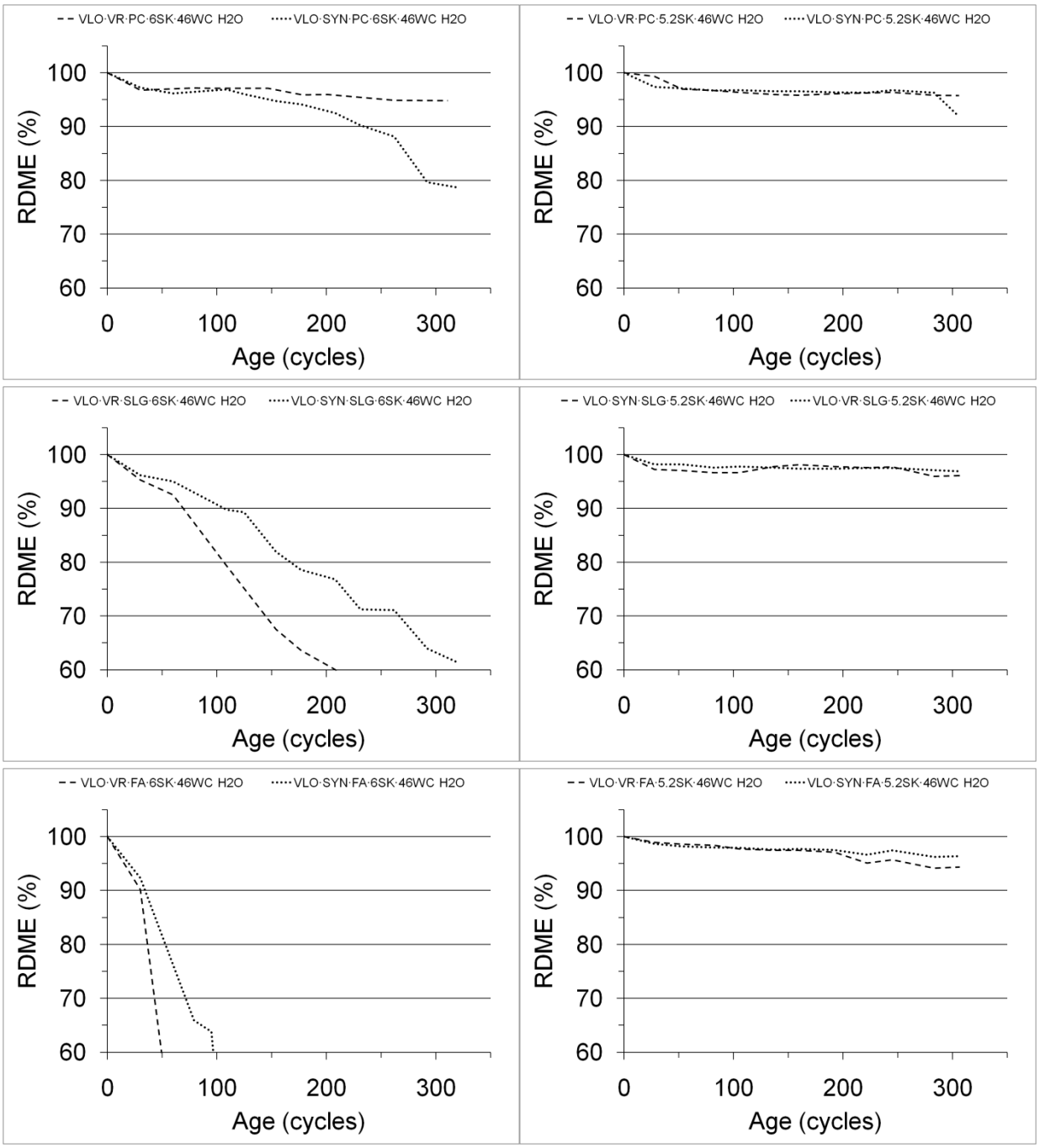

Figure 35: Relative dynamic modulus of elasticity plots for the Phase III very low air content 0.46 *w/cm* mixtures frozen in water (ASTM C666 Procedure A). From left to right, 564 lbs/yd^3 CMC mixtures vs. 490 lbs/yd^3 CMC mixtures. From top to bottom: straight portland cement mixtures, 40 wt. % substitution slag cement mixtures, and 25 wt. % substitution fly ash mixtures. Dashed lines denote mixtures with vinsol resin AEA; dotted lines denote mixtures with synthetic AEA.